DISPOSAL OF THE SEWAGE OF LAKE FOREST, ILLINOIS

BY
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THE DISPOSAL OF THE SEWAGE
OF
LAKE FOREST, ILLINOIS.

A Study of the Present System and the Design of a New Plant.

A THESIS

Presented by

FREDERICK GUSTAV HEUCHLING

to the

President and Faculty

of

ARMOUR INSTITUTE OF TECHNOLOGY

For the Degree of Chemical Engineer.

1910.

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INTRODUCTION.

Up to within the last ten years Lake Michigan has served the double purpose of a source of water supply and an agent in sewage and waste disposal for those communities lying along its shores. Of late years, however, so great has been the increase in the population of these districts and the large number of manufacturing establishments which have been set up in them, that Lake Michigan has proven incapable of suitably diluting the greatly increased amount of sewage and waste, and at the same time furnishing a supply of water sufficiently pure for drinking and domestic use.

The City of Chicago, being the largest city lying on the shores of Lake Michigan, naturally was the first to feel the necessity of protecting its water-supply by finding some other disposition of its sewage than that of diluting it in the lake. As a solution of this problem, in the year 1900 the Sanitary and Ship Canal was thrown open. This canal extends from the South Branch of the Chicago River to the City of Joliet, - a distance of thirty-five miles, - at which place its waters mingle with those of the Des Plaines River and flow into the Illinois River, from whence they pass into the Mississippi. At the present time this canal serves as a means for the inoffensive disposal of the sewage of that part of Chicago bordered by 87th Street on the South and Howard Avenue on the North. In addition, an auxiliary canal is being constructed which will carry the sewage of the towns of Evanston and Wilmette to the Sanitary Canal. Another auxiliary canal,

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known as the Calumet-Sag Canal, is proposed for the purpose of carrying the sewage of the towns lying between 87th Street and 159th Street, and between the Indiana State line and 40th Avenue.

When these latter projects have been completed the Drainage Canal will be taxed to its fullest capacity; that is, it will carry 14,000 cubic feet per second, and will be diluting as much sewage as that volume of water is capable of diluting, assuming a rate of 3.33 cubic feet per second for the sewage of each 1,000 persons. If a greater volume than this were to be drawn from Lake Michigan an appreciable lowering of the level of that body of water woulf result, with a consequent damage to harbor and shipping facilities. It is therefore necessary for the towns North of Wilmette to resort to other methods of sewage disposal in order to properly protect their water supply. Most of the municipalities lying on the shore of Lake Michigan do not attempt to purify their sewage before discharging it into the Lake, although they all withdraw drinking water from it at points which are in some cases less than a quartermile from the shore along which the sewers empty.

The City of Lake Forest, situated some twenty-eight miles North of Chicago, has always been very progressive in matters dealing with the public welfare, and in the year 1902 a plant was built for the purification of its sewage, so that it could be discharged into Lake Michigan without affecting the drinking-water which is withdrawn therefrom. This plant served its purpose satisfactorily for a number of years, but numerous extensions to the sewers which have been made since its instal-

lation, together with the excessive leakage of ground water into these sewers, - which are supposed to carry only domestic waste, - have acted together to render the disposal plant entirely inadequate.

The purpose of this work has been to study the condition and effectiveness of the present plant, and to gather as much data as possible bearing on the design of an additional plant, so that the combined installation would be able to successfully purify the present sewage emptied into the lake, and at the same time provide for such a future increase in the amount to be handled as is to be reasonably expected. The circumstances under which this work was performed did not allow of so extensive a study of conditions as has been made for similar purposes at Columbus, Ohio, Saratoga Springs, New York, or at Chicago, Illinois. At the same time, the extensiveness of this study, as compared to those mentioned above, is entirely commensurate with the size and monetary value of the proposed plant, and it is not to be expected that an exhaustive study should be made, at a cost of several thousand dollars, in order to properly design a plant that itself costs only ten or fifteen thousand dollars.

The material will be presented under the following heads:

I. Topography, Present Sewage System, and probable future additions thereto.

II. The Lake Forest Water Supply and its Relation to the Disposal of the Sewage.

III. Generalities Bearing on the Disposal of Lake Forest Sewage.

IV. Chemical Studies of the Raw and Treated Sewage.

V. Bacteriological Studies of the Raw and Treated Sewage.

VI. Description of the Present Plant, its Condition and Efficiency.

VII. The Character and Quantity of Sewage to be Purified.

VIII. The Proposed New Plant, its Description, Design, and Cost.

I.

Topography, Present Sewerage System, and Probable Future Additions Thereto.

The City of Lake Forest is situated on the Eastern shore of Lake Michigan, twenty-eight miles North of Chicago, and has a water-front of approximately three and one-half miles. The corporation limits extend inland to the Green Bay Road, a distance of about one and two-thirds miles, and there are three additions.to the city which lie West of said Road, and are situated as shown on the accompanying map. The total area of the city is about seven and one-half square miles, and while the land West of the Northwestern Railway tracks is very level, the tract lying between these tracks and the lake is more hilly and is traversed by a network of ravines. Except for the breaks in the contour brought about by these ravines, the topography is fairly level, varying from one to four per cent slopes.

The streets East of the Northwestern Railway are laid out in a very irregular manner, as a glance at the map will show. The purpose of this is to lend an artistic effect to the grounds and parks which cover this entire area. The streets all drain into the nearest ravine, which serves to conduct the surface runoff to the lake. The result is that during a heavy rain the ravines carry a considerable amount of water. The sewer mains for the transmission of the domestic sewage are, for the greater part, laid along the bottoms of the ravines, so that there is every facility for the surface drainage to leak into the domestic sewers. The depth of the ravines, which varies from twenty to one hundred feet at different localities, causes a

very rapid drainage of the surfaces, and produces a great rush of storm water during heavy rains. This explains the large amount of storm water that finds its way to the sewage disposal plant, although the latter has been designed to handle only the domestic sewage. The streets East of the Northwestern Railway tracks are paved with macadam, while those West are paved with vitrified brick and wooden blocks, the former predominating. Some of the streets in the Western part of the town are still unpaved, and therefore have little effect on the storm water leaking into the domestic sewers.

The domestic sewage of Lake Forest is conducted to the disposal plant by a system of sewers which is entirely independent of the street drains. A municipal ordinance prohibits the connection of roof drains to the sewers, but the drainage of cellars may be run into them. For the most part the sewer mains are laid in the bottoms of the ravines, as stated before. The layout of the system is indicated on the accompanying map, which shows the present sewer mains in heavy, solid lines.

The sewers in the northern district lead into a twelve-inch main, which discharges into a six-inch cast iron carrier at the lake shore about three quarters of a mile North of the disposal plant. The size of this carrier is ample, because of the steep grade on which it is laid. A ten-inch main leads from the addition to the city West of the Green Bay Road, to the system in the North district. The sewers in the central portion of the town are connected to the disposal plant by a twelve-inch carrier. This central system carries by far the greater part of the domestic sewage, as it drains the district in the neighborhood of the railroad depot, and that part of

the town West of the railroad in which most of the stores and business establishments are situated. The Southern part of the town is not as yet built up to any extent, and no sewers are installed.

The heavy dotted lines on the map indicate the most probable location of future sewer mains. The drainage of the Southern district will be effected by eight and ten inch mains, which will lead to a six inch cast iron carrier laid along the lake shore, as has been done in the Northern district.

The total length of eight and ten inch mains at present installed in the Northern district is 22,000 lineal feet. These drain into 3600 feet of twelve inch main, which in turn drains into 5000 feet of six inch carrier. In the central district there are 52,300 lineal feet of eight and ten inch mains leading into 4500 feet of twelve inch pipe, which empties directly into the disposal plant. The total length of sewers is 87,400 lineal feet. The greatest distance through which the sewage must travel before reaching the purification plant is along the main leading from the addition lying West of the Green Bay Road at the Northern end of the town, and there is not likely to be a longer main installed when all extensions have been laid. The distance from the extreme end of this main to the disposal plant is about four miles. In the other mains the sewage is required to flow through a much less distance than this, so that the major portion of the sewage reaches the plant in a fresh condition.

In the design of the disposal plant it will be necessary to take account of 16,000 lineal feet of eight and ten inch mains, to be added to those at present laid in the North

district, 16,200 lineal feet to be added to those in the central district, and sewers for the entire Southern district, which will eventually consist of 30,000 feet of eight and ten inch mains, and 4400 feet of six inch carrier. 66,600 lineal feet must thus be provided for, in addition to the present length of 87,400 lineal feet. This is an increase of about seventy-one percent.

II.

The Water Supply and Its Relation to the Disposal of the Sewage.

The City of Lake Forest is furnished with water for all purposes by the Lake Forest Water Company. The water is drawn from Lake Michigan through a cast iron intake, which extends out eleven hundred feet from the shore. This intake is laid on a grade sloped toward the shore, so that the water flows into a pump-well by gravity. A compound direct-acting duplex pump withdraws the water from the well, and delivers it to a standpipe near the Town Hall. The pump has an eighteen inch stroke and twelve inch cylinder, and is usually run at about twenty strokes per minute, against a pressure of eighty-five pounds per square inch. Its rated capacity is one million gallons per day, and this amount is more than sufficient to supply water for the city for domestic purposes and for street and lawn sprinkling. The pumping station is equipped with an auxiliary pump of the same type as the one described above, and of one-half the capacity, which is used in case of fire in the town, or in case of a break-down of the larger pump.

The total capacity of the pumping plant is thus seen to be one and one-half million gallons per day, but the quantity used for domestic purposes is not more than 300,000 to 400,000 gallons per day, the remainder being used for lawn and street sprinkling and for the fire mains. This water is purified by coagulation with alum, which is automatically added to the water in the pump-well at the rate of six or seven pounds per day. Mixing and precipitation takes place in the well, and the water

is delivered from the pump to six pressure filters, each six feet in diameter, These filters were installed by the O. H. Jewell Filter Co., and the water is delivered to them at a pressure of sixty pounds per square inch, and leaves at a pressure of about fifty-five pounds.

The regulation and control of the purification process is very poor, the sole object being to clarify the supply. The small amount of coagulant used is not sufficient to produce a very great reduction of the number of bacteria in the raw water, and the purification process can not be relied upon to thoroughly purify a contaminated supply of water.

The pumping station is situated at the North end of the town, about one and three-quarters miles north of the sewage disposal plant. In quiet weather there is a possibility of currents along the shore carrying the effluent from the disposal plant toward the intake of the water works, and producing contamination of the water supply. During heavy wind storms, when the surface water is driven inshore, there is the same danger of the sewage being carried to the water works intake. However, if the effluent from the disposal works is free from organic matter that is putrescible, and if it contains no more than ten or twenty thousand bacteria per cu. cm., it should have no injurious effect on the water supply whatever. The bacteria passing from an open sand filter are not of an injurious nature ordinarily, and the dilution in the lake soon destroys them by reason of the lack of food supply.

From the latest school census the population of Lake Forest is estimated at three thousand. Judging from the

amount of water supplied to the town, and the large number of people of the wealthier classes residing in it, we may place the quantity of water used at from 100 to 135 gallons per inhabitant per day. This eventually finds its way to the sewage disposal plant, which should therefore be capable of handling from 300,000 to 400,000 gallons per day, no provision being made for a future increase in the amount to be purified, and no reserve capacity being provided for the storm water leaking into the sewers.

III.

Generalities Bearing on the Sewage Disposal Question.

The large number of investigations of water supplies and sewage disposal plants that have been carried on both in this country and abroad, have all made it very clear that no process of sewage disposal which can be economically carried on by a municipality, will serve to produce at all times, an effluent that is entirely free from injurious bacteria, and contains no decomposable organic matter. However, if the effluent contains only a reasonable number of bacteria, if the suspended solids are very small in amount, and if the dissolved organic matter has been nearly all transformed into harmless nitrates or stable organic compounds, a reasonable amount of dilution will bring about a thorough purification through the action of aeration and sedimentation.

Applying this reasoning to the purification of the sewage of Lake Forest, it is believed that the only requirements of a disposal plant for that City are that the effluent shall be clear and entirely non-putrescible, and shall contain enough dissolved oxygen to take care of the nitrites and unoxidized organic matter that are contained in it. If these requirements are fulfilled, the number of bacteria will not be excessive, and dilution in Lake Michigan will provide for the complete purification of the remaining organic matter, and for the destruction of any harmful bacteria that may pass through the plant.

IV.

Chemical Studies of the Raw and Treated Sewage.

The chemical analysis of a sewage and its products offers a great deal of information in regard to the changes occurring in the suspended and dissolved matter contained therein, both as to the quantity and character of these latter. While much is to be learned from the bacterial studies of sewage products, it is to be remembered that the prime purpose of a sewage disposal plant is the removal of dissolved and suspended matters, or their transformation into substances which are not injurious when taken into the human system, and which will not in time develop into substances of this last nature. While bacterial activity is almost entirely responsible for this transformation of harmful into harmless substances, the completeness of the process is best indicated by the chemical analysis. The bacterial studies are of value as an adjunct to the facts disclosed by the chemical examination, and are the surest means of detecting the source of trouble in a purification process.

For a thorough study of a sewage both the chemical and bacteriological examinations are of equal importance, and they should be considered in conjunction with each other. In this work samples for chemical and bacteriological examination were taken at the same time, and the examinations were carried on simultaneously, as much attention being paid to the one as to the other. The samples were taken at different times of the day, and on different days of the week, but it was not possible to arrange the collection of hourly samples for an

entire day, nor to get a sample on each successive day for a week. There is considerable variation, however, in the times at which the collections were made, and as samples were taken during both dry and rainy weather, it is believed that the results are sufficient to show the degree of purification which is effected, and to give data for the proper design of an additional plant.

The analyses were made as soon after collection as possible, and most of the determinations were started within seventy-two hours. Most of the bacterial examinations were made the same day that the sample was collected. Samples of the raw sewage were taken at the entrance to the settling chambers, and samples of the septic sewage at the entrance to the filter beds, while the purified sewage was sampled at the manholes between the filter beds. The term "purified sewage" as used here, must not be confused with the effluent from the plant, for at no time during the period of these examinations was all of the sewage purified. The amount of sewage flowing down to the plant was sometimes as much as three or four times as much as could be treated, and the excess flowed directly into the lake, after being mixed with the portion that had passed through the purifying devices. At times the amount of sewage was so great that the mixture of treated and untreated effluent that flowed into the lake was hardly distinguishable from the raw sewage, both in appearance and chemical composition.

The methods of analysis used may be briefly described as follows:

Total Solids. One hundred c.c. of the sample was evapo-

rated on a water bath in porcelain. The residue was dried at 110 degrees centigrade for one hour and then wieghed.

Volatile Matter. The dried residue from the determination of total solids was ignited to redness and the loss in weight calculated as volatile matter. This was largely organic matter, with a small amount of carbonates and ammonium salts.

Suspended Solids. Fifty c.c. of the sample were filtered through a weighed gooch crucible, and the residue dried and weighed. To insure an accurate sample the fifty c.c. were withdrawn in five ten-c.c. portions, the bottle being thoroughly shaken each time a portion was removed.

Suspended Organic Matter. The residue from the above determination was ignited to redness and weighed. The loss is practically all organic matter, except for the hygroscopic water in the iron salts, and the negligible amount of carbonates in suspension.

Chlorine. This was determined by titration with standardized silver nitrate, using potassium chromate as an indicator.

Nitrogen. Free ammonia was determined by distillation of fifty c.c. of the sample with five hundred c.c. of nitrogen-free water, and five c.c. of a twenty-five per cent solution of sodium carbonate.

Albuminoid ammonia was determined by distillation of the residue from the free ammonia after the addition of fifty c.c. of alkaline permanganate solution.

A few estimations of the total organic nitrogen in the raw and septicized sewage were made, and for this purpose the

regular Kjeldahl method was followed.

Nitrates were determined by the treatment of the sample with phenol-disulphonic acid and comparison with a standard potassium nitrate solution, treated similarly.

The determination of nitrites consisted in the comparison of the sample with a standard solution of sodium nitrite after treatment of each with sulphanilic acid and napthylamine hydrochloride.

Oxygen Consuming Power. - This determination was made by boiling fifty c.c. of the sewage for five minutes with standard potassium permanganate, after acidulation with sulphuric acid. The excess of permanganate was determined by titration with oxalic acid.

Dissolved Oxygen. - The oxygen dissolved in the sewage and its products was estimated by adding manganous sulphate and sodium hydrate-potassium iodide solution to a sample of about two hundred and fifty c.c. contained in a calibrated bottle. The sample and reagents entirely filled the bottle, and, after shaking, the precipitate was allowed to settle and further action prevented by the addition of sulphuric acid. This procedure was carried out directly after the sample was collected and the precipitated iodine was determined by titration with sodium thiosulphate at a later time. From the iodine liberated the amount of oxygen dissolved in the original sample was calculated.

Putrescibility. - The samples were tested to determine their tendency to putrefy by completely filling a bottle of about two hundred c.c. capacity and storing it at a temperature

of about 37 degrees centigrade for forty-eight hours. At the end of that time the stopper was removed and the sample examined for odor and any blackening of the sediment. None of the samples showed blackening of the sediment, and the results given in Table **I** state whether the odor was decided, slight or absent.

TABLE I. RESULTS OF CHEMICAL ANALYSES.

Sample No.	Date Day, and Time	Character of Sample	Appearance.	Odor	Total Solids		Suspended Matter		Chlorine	Nitrogen					Oxygen Consumed	Oxygen Dissolved	Putrescibility in 48 hours.	Sample No.
					Total	Volatile	Total	Volatile		Free NH$_3$	Album. Ammon	Total organi	Nitrate	Nitrites				
1	Saturday, April 16, '10.-3^{20} p.m.	Raw Sewage	Muddy	Sewage	1390	683	642	294	39	4.92	2.1	15.3	.53	.00	42	32	Decided.	1
2	Ditto.	Septic Effluent.	Turbid	Sewage	1183	602	432	386	39	2.9	1.8	14.1	—	—	30	—	—	2
3	Ditto.	Filter Effluent	Clear Colorless	Odorless	688	301	42	24	41	1.4	.86	—	.72	.08	8.1	5.0	None.	3
4	Ditto.	Lake Outfall	Turbid	Sewage	1007	493	488	236	42	5.2	1.96	14.7	.62	.012	46	2.3	Slight.	4
5	Friday, April 29, '10.-5^{30} p.m.	Raw Sewage	Turbid	Sewage	737	436	144	88	47	8.3	4.3	11.0	2.1	.013	28	0.0	Decided	5
6	Ditto.	Septic Effluent	Turbid	Sewage	703	387	244	120	44	4.2	3.9	—	—	—	21	—	—	6
7	Ditto.	Filter Effluent	Clear Colorless	Odorless	593	193	33	31	32	.3	1.2	—	2.3	.02	12	3.2	None	7
8	Ditto.	Ditto.	Clear Colorless	Odorless	632	205	82	61	38	.08	2.3	—	3.3	.04	16	6.2	None	8
9	Ditto.	Lake Outfall	Turbid	Slight Sewage	694	201	136	98	41	7.0	3.7	9.0	1.3	.016	20	.3	Noticeable	9
10	Monday, May 2, '10.-6^{00} p.m.	Raw Sewage	Muddy	Sewage	542	313	203	130	52	11.0	3.9	—	1.8	.09	22	2.1	Noticeable	10
11	Ditto.	Septic Effluent	Turbid	Septic	523	292	105	93	55	4.0	4.1	—	—	—	16	—	—	11
12	Ditto.	Filter Effluent	Clear	Odorless	482	210	00	00	49	.26	.68	—	1.6	.00	11	7.3	None	12
13	Ditto.	Lake Outfall	Turbid	Sewage	510	296	180	172	61	9.8	3.6	—	2.3	.06	21	1.6	Decided	13
14	Saturday, May 15, '10. 3^{00} p.m.	Raw Sewage	Turbid	Sewage	680	402	176	120	43	12.3	2.8	—	3.1	.12	18	4.0	—	14
15	Ditto	Septic Effluent	Turbid	Septic	492	421	98	48	37	2.6	2.1	—	—	—	14	—	—	15
16	Ditto	Filter Effluent	Clear Colorless	Odorless	476	283	00	00	41	.18	.23	—	4.3	.02	7.3	6.7	None	16
17	Ditto.	Lake Outfall	Turbid	Slight Sewage	706	407	198	106	39	12.0	3.1	—	2.8	.10	23	2.8	Decided	17

NOTES:—Blank spaces indicate determinations not made.
All results expressed in parts per million.

V.

Bacteriological Studies.

In making the bacteriological examinations, the importance of careful preparation of the culture media and the necessity of making the tests as soon after collection as possible, were kept in mind at all times. All media were prepared after the recommendations of the Committee on Standard Methods of the American Public Health Association. Especial care was taken in adjusting the reactions of the media as recommended by the above Committee. Instead of using meat infusion for the agar and gelatin, however, it was found necessary to substitute beef extract in order to expedite matters. The inoculation of cultures was performed a few hours after collection of the samples in most cases, and in no case was the inoculation done after a greater interval than twenty-four hours.

The total number of bacteria growing on agar at 37 degrees and on gelatin at 20 degrees was determined for the crude sewage, the outfall at the lake, and the effluent from the filter beds. The number of acid producing bacteria growing on litmus-lactose-agar at 37 degrees was determined on samples from the filter effluents and the outfall at the lake in all cases. The total number of bacteria in the effluent from the septic tank was not considered of enough importance in this work to warrant investigation, and for the same reason the numbers of acid-producing bacteria in the crude sewage were not determined. The purpose of the bacteriological studies was to determine the numbers of bacteria ordinarily found in the sewage, in order to ascertain, to a certain degree, how long a period of incubation occurred before the sewage reached the plant. Further

it was necessary to determine the total numbers of bacteria and the numbers of acid-producing or injurious bacteria in the effluents from the sand filters, in order to show whether they were efficient in purifying the applied septicised sewage. Since all the sewage did not pass through the septic tank and sand filters the effluent from the latter was not by any means representative of the final effluent at the lake outfall. For that reason it was necessary to make the same examinations on the sewage from the lake outfall as were made on the effluent from the sand filters. In order to further test these effluents for the presence of colon bacilli and other intestinal organisms, one c.c. of a one to ten dilution of the samples was incubatedwith sterilized ten percent glucose broth. The formation of gas, especially in the proportion of two of hydrogen to one of carbon-dioxide, was considered a conclusive proof of the presence of intestinal bacteria.

The gelatin plates were examined for the number of colonies showing liquefaction of this medium, and a record of these observations was kept, as a more or less valuable indication of the numbers of injurious organisms in the respective samples.

TABLE II. BACTERIOLOGICAL EXAMINATIONS.

Sample No.	Date, Day and Time.	Sample from	Total Bacteria per c.c. on Agar 37°	Total Bacteria per c.c. on Gelatin 20°	No. Liquefying Gelatin.	No. of Acid Prod. on Litm. Lact. Agar	Gas Production	Ratio $H:CO_2$	Sample No.
1	Saturday, April 16, 1910, - 3^{30} p.m.	Raw Sewage	8,100,000	200,000	45,000	534,000	—	—	1
2	Ditto.	Septic Effluent	—	—	—	—	—	—	2
3	Ditto.	Filter Effluent	63,000.	4,000	none	11,000	+	2:1.5	3
4	Ditto.	Lake Outfall	6,300,000	230,000	xxxx	830,000	+	2:0.8	4
5	Friday April 29 1910. 5^{30} p.m.	Raw Sewage	2,450,000	102,000	25,000	560,000	—	—	5
6	Ditto.	Septic Effl.	—	—	—	—	—	—	6
7	Ditto.	Filter Effluent	2,300	540	none	3	-	-	7
8	Ditto.	Filter Effluent	3,420	1,360	23	125	-	-	8
9	Ditto.	Lake Outfall	3,200,000	92,000	37,500	93,000	+	—	9
10	Monday May 2, 1919 - 6^{00} p.m.	Raw Sewage	3,500,000	1,010,000	xxxx	302,000	—	—	10
11	Ditto	Septic Effluent	—	—	—	—	—	—	11
12	Ditto.	Filter Effluent	9,000	2340	none	830	+	1:1.1	12
13	Ditto.	Lake Outfall	2,930,000	67,000	xxxx	108,000	+	2:1.3	13
14	Saturday, May 15, '10. 3^{30} p.m.	Raw Sewage	1,830,000	137,000	68,000	289,000	—	—	14
15	Ditto.	Septic Effluent	—	—	—	—	—	—	15
16	Ditto.	Filter Effl.	7700	1830	42	240	-	-	16
17	Ditto.	Lake Outfall	1,240,000	322,000	103,000	135,000	+	1:1	17

NOTES:- Blank spaces indicate determinations not made.
xxxx Indicates liquefaction of entire gelatin plate.

VI.

Description of the Present Plant. Its Condition and Efficiency.

The installation that is now used for the purification of the sewage of the City of Lake Forest is shown in plan on Plate I. The main carrier from the central sewerage district is laid in the bottom of a ravine behind the disposal plant, and a twelve inch pipe "A" leads the sewage to the mixing chamber at "B". There is a by-pass allowing direct passage of the sewage into the lake without entering the mixing chamber, and this pipe has been marked "H" on Plate I. The six inch carrie from the north district is laid along the ends of the filter beds, and leads to the mixing chamber through the pipe "D". From the mixing chamber the sewage enters the septic tank through six 6-inch shear valves. An overflow wier in the mixing chamber allows the excess of sewage, which would overtax the septic tank and filters, to flow directly to the manhole between beds 1 and 2, and from thence it passes into the outfall to the lake.

The fore part of the septic tank is divided longitudinally into two compartments which serve as sedimentation chambers. Three of the shear valves from the mixing chamber lead into each of these compartments, rendering the latter independent of each other. The sedimentation chambers have a bottom of concrete six inches thick, which slopes toward the south end at the rate of one half inch to the foot. At the lower end of each tank there is a ten inch shear valve leading into a sludge pipe. Each sedimentation chamber is twenty-five feet long, eight feet four inches wide, and eight feet deep, and has a capacity of about twelve thousand gallons. From each sedimentation tank three shear valves lead into a trough "M" extending

across the ends of the two tanks. This trough is one foot six inches wide and four feet deep, and serves to lead the sewage from either of the sedimentation chambers into any one of the three hydrolytic tanks "K".

The hydrolytic tank at the west side is thirty-two feet long, seven feet wide, with an average depth of six feet eight inches, and has a capacity of about eleven thousand two hundred gallons. The middle tank is the same length and depth, and five feet wide, with a capacity of about eight thousand gallons, while the tank on the east side is but four feet wide, with a capacity of about six thousand four hundred gallons. All three of the tanks "K" have a bottom of six inches of concrete, sloped at the rate of one half inch to the foot toward the south end, where eight inch shear valves allow of emptying the sludge into the sedimentation chambers.

By shutting off the easterly hydrolytic tank the time of flow of sewage through the tanks can be cut down twenty-five percent, while by closing off both the middle and easterly tanks, the time of flow may be cut down to less than half what it is when all three tanks are in service. This is assuming a constant rate of feed of the sewage from the sedimentation chambers. A similar process of control can be applied in order that the sewage may not be subjected to septic action too long during periods of extreme dry weather flow. This method of construction was designed when the volume of sewage flowing down to the plant was much less than it is now, and at the present time the rate of flow through the sedimentation tanks "J"is much greater than that through the middle and westerly hydrolytic tanks. The easterly hydrolytic tank is left open

and the excess of sewage coming from the sedimentation tanks over that flowing through the middle and westerly tanks, passes directly through the easterly tank into the dosing chamber, without being subjected to any further treatment than that received in the sedimentation tanks.

From the hydrolytic tanks the septicised sewage passes over wier gates into the distributing or dosing chamber. This latter is twenty-four feet wide, eighteen feet long and three feet deep, having a capacity of about eight thousand gallons. Each time the distributing chamber fills with sewage, its contents are emptied through one of ten siphon outlets, in rotation. Each of these outlets leads to one of the ten sand filter beds, which are thus dosed with the septicised sewage in regular order. A twelve inch pipe "P", fitted with a shear valve, extends from the dosing chamber to the drain underneath the filter beds, and may be utilized to carry the septicised sewage directly to the lake outfall without filtration, at times when the beds are clogged or frozen over.

The sand filters are ten in number, and range in area from three thousand square feet for bed number 1, to twenty-seven thousand square feet for bed number 9, which is the smallest. These beds are constructed of Lake Michigan sand obtained at the site of the plant, which is of a very fine qaulity, eighty-five percent.passing a forty mesh sieve, and forty-two percent passing a sixty mesh. The beds are about five feet deep, and the sewage coming from the dosing chamber passes through a ten inch pipe with a concrete outlet at the entrance to each bed. At the bed the sewage flows into a wooden trough "G" which is laid on the surface of the bed and extends to the

farther end. The sides of these troughs have small openings in them, through which the sewage is fed in fine streams. In this way the sewage is distributed over the surface of the sand, and does not strike it with enough force to wash out holes and furrows. The beds are drained by tile "F", laid with open joints, which carry the filtered sewage to a main pipe leading to the outfall. Between the beds manholes "N" are provided. The lake outfall is a twelve inch cast iron pipe, and a pier is built alongside of it to prevent scour. Two protection piers are built at the shore of the lake opposite the filter beds in the position shown on Plate I, in order to prevent scour of the shore along the beds, which are set about ten feet above mean water level.

This disposal plant, as originally designed, was intended to treat about two hundred and twenty-five thousand gallons of sewage per day. At that rate the beds would be filtering about three hundred thousand gallons per acre per day, and the sewage would have a rest period of about six and one-half hours in the septic tank. That the sewage could be sufficiently purified by this treatment, provided the plant received the proper care and control, will be further brought out in the next few pages. But the amount of sewage which reaches the plant at the present time ranges from six to eight hundred thousand gallons per day, and the plant is entirely incapable of handling that amount. These facts will be more clearly expounded in the following pages, and their proofs will be outlined from the analyses and examinations made in connection with this work.

An examination of the analyses given in Table I will show

that the effluents from the filters are at all times satisfactory, and that, in general, the treatment is sufficient to answer all the requirements of the process. Analyses numbered 3, 7, 8, 12 and 16, are those made on samples taken at the manholes between the filter beds. The nitrites are very low, ranging from .08 parts per million to none at all. The albuminoid ammonia content, which is a measure of the undecomposed animal matter remaining in the effluent, ranges from 1.2 to .23 parts per million, and this is not excessive for this type of filter. In one instance the albuminoid ammonia ran as high as 2.3 parts per million, but the nitrites were low, and the sample showed no tendency to putrefy after incubation for forty-eight hours at 37 degrees centigrade, so that its character could not be condemned.

All of the analyses showed that the effluents from the filters contained an amount of dissolved oxygen ranging from thirty to ninety percent of the oxygen consumed, so that the effluent is in every case capable of further purifying itself without the aid of dilution in the lake. Table II gives the results of the bacteriological analyses of these same samples. The bacterial content was in most cases below ten thousand per cubic centimeter, with less than 900 acid producing organisms per cubic centimeter. As there is no sand filter in operation at the present day that will hold all of the myriads of intestinal organisms that are applied daily, these results are good, and indicate that the filters at this plant are satisfactory. One analysis, (that made on April 15th,) showed a content of eleven thousand acid producing organisms per cubic centimeter, but this sample was taken during a heavy rainfall, and the fil-

ters were overtaxed. Samples numbered 7 and 16 showed very few acid producing organisms, and one cubic centimeter of a 1:10 dilution of these samples showed no gas production when incubated with glucose broth. Samples number 3 and 12 gave a production of gas when incubated with glucose broth, and there was every indication that intestinal bacteria passed through the filters at these times. Two of the filter effluents, (number 8 and 16) contained organisms that liquefied gelatin, but the other samples were free from them.

It is believed that these examinations, together with the chemical analyses, make it clear that the sand filters are of satisfactory design and are capable of freeing the sewage of putrefactive matter and the greater number of injurious organisms so that it may safely be emptied into the lake without contamination of the water supply taken from neighboring intakes, provided that the amount of sewage applied is not greater than the beds are capable of handling.

The reduction in the amount of suspended matter in the raw sewage brought about by its passage through the septic tank, is sufficient to prepare it for the filter beds, as shown by the determinations of suspended solids in the septicised effluent. However, at times of heavy rainfall, such as occurred on April 16th, the sewage passes through the tank at a too rapid rate, and a tank of greater capacity is necessary for the proper hydrolysis of the sewage at all times.

At no time during the period that these examinations were made was more than half of the total volume of sewage reaching the disposal plant passed through the septic tank and sand filters, and at certain times less than one third of the sewage

could be handled by the present installation. The plant is only capable of properly purifying from two hundred to two hundred and fifty thousand gallons of sewage per day, and it should have a capacity of at least six or seven hundred thousand gallons in order to take care of the large amount of storm water and street drainage that leaks into the sewers.

These facts are best brought out by a consideration of the examination of the effluent at the lake outfall, as compared to those of the effluent from the sand filters. While the latter were shown to be of a satisfactory character, the sewage at the lake outfall always contained a large amount of solid matter in suspension, and was muddy in appearance. All the samples from the outfall putrefied after incubation for forty-eight hours, and in every case the amount of oxygen in solution was very small as compared to the amount of unoxidized material remaining in the sewage. The bacterial analyses were all sufficient to show that this effluent was not satisfactory, and that it was not much better than the raw sewage. The small part of the total sewage which passes through the plant has so little effect on the resultant mixture of treated and untreated sewage, that the present plant is of very little value, and unless it is enlarged there is little advantage to be gained by keeping it in operation. The following chapters will take up the question of the design of an additional plant, which, in conjunction with the present installation, will be capable of purifying all the sewage reaching the plant, with enough reserve capacity to take care of such an increase in the quantity to be handled in the future as may be predicted from the present conditions.

VII.

The Character and Quantity of Sewage to be Provided for.

In order to intelligently design any plant for the efficient purification and disposal of sewage, it is necessary that data be collected concerning the character and quantity of sewage to be treated, and that studies be made of the most advantageous method of treatment. In addition to this the necessary degree of purification must be decided by a consideration of the final disposal of the purified sewage, and the effect of the latter on the neighboring surface or ground waters which are used as sources of domestic water supply.

Taking up these matters in the reverse order to that mentioned above, the effect of diluting the purified sewage of Lake Forest in Lake Michigan, will be considered first. The nearest intake for a water supply is that of the Lake Forest Water Company, situated about one and three-quarters miles north of the disposal plant. The only other intake that might be affected by the sewage of Lake Forest is that situated at Fort Sheridan, which is nearly three miles south. Since the prevailing winds in this locality are from the South and East, and because of the fact that the currents along this shore are very slight and generally take a northerly direction, the effect of the Lake Forest sewage on the Fort Sheridan intake need not be considered. As for the effect of the sewage on the Lake Forest water supply, if the effluents are free from suspended matter and show no tendency to putrefy, the great degree of dilution which takes place in the waters of the lake may be safely depended upon to completely alter any remaining undecomposed organic matter into harmless compounds, while the

effect of the sunlight and paucity of food supply should certainly kill all injurious organisms before they can be carried to the intake. The effect of the diluted sewage on the ground water withdrawn from shallow wells near the shore is so slight as to be negligible.

We may then say that the sewage turned into the lake need only be free from sediment and show no tendency to putrefy. The bacterial content will not be excessive if these conditions are fulfilled. If the effluent was to be emptied into a river or smaller body of water, or if an intake of a water supply were situated closer to the disposal plant it would be necessary to resort to disinfection of the effluent, or aeration of the septicised sewage, followed by double sand filtration. In the present instance, however, the degree of purification attained by the proper use of the filters and septic tank is satisfactory in every way, and all that is necessary is an increase in the capacity of the plant.

As regards the method of treatment to be applied in the design of additions to the present plant, the studies that were made of the present appliances are sufficient to prove that the method now in use will be satisfactory for the new portion.

The quantity of sewage which the new plant should be capable of treating may be arrived at from the population of the city, assuming a certain production of sewage per capita, and allowing for a reasonable increase in the population; or it may be estimated from the quantity of sewage now flowing down to the disposal plant, the proper allowance being made for additions to the sewerage system and a reserve capacity

being provided for the storm water leaking into the sewers.

As stated in Chapter II, the population of Lake Forest is about three thousand, and assuming a water consumption of from one hundred to one hundred and thirty-five gallons per day per capita, the disposal plant must be capable of handling from three to four hundred thousand gallons of sewage per day, to say nothing of the storm water leaking into the sewers. With the increase in the population which is to be expected, and the laying of sewers in the south district, as detailed in Chapter I, an increase of about seventy per cent in the quantity of sewage to be disposed of is to be expected. The combined present plantand the addition, should therefore be designed to handle six hundred and eighty thousand gallons of sewage per day.

If the septic tanks and filters are designed to handle this quantity of sewage during normal conditions, it will be possible to pass at least eight hundred thousand gallons of sewage through the plant for short periods at a time during heavy rains, and thus take care of storm water.

The sewage of Lake Forest is almost entirely free from industrial or trades waste, and the analyses of the raw sewage given in Table No. I indicate that it is not of a strong composition. During storms the total amount of solid matter in suspension and solution may reach as great a value as fourteen or fifteen hundred partsper million, but the greater part of this is surface wash, and it should not give trouble in the purification process. The average sewage reaching the plant contains from five to eight hundred parts of solid matter.

The sewage is of a fresh character, however, and reaches the plant in the space of two or three hours, so that septic action must take place almost entirely within the plant. For strong sewages, and for those of larger cities, where there are large quantities of manufacturing wastes to be purified, it is necessary to allow a rest period of at least eight hours in the septic tank. The present plant is designed to allow a rest period of only six and one-half hours, and this time seems to be perfectly satisfactory for the kind of sewage to be purified here, so that this feature will be adhered to in the design of the additional plant. The design will be made so that this rest period can be established during times of heavy sewage flow, and it will be possible to increase the time allowed for septic action during periods of dry weather.

VIII.

Proposed New Plant. - Its Description & Design.

The present plant is capable of satisfactorily purifying two hundred and twenty-five thousand gallons of sewage, so that the additional plant will be designed to handle four hundred and fifty-five thousand gallons, bringing the total capacity of the plant up to the required six hundred and eighty thousand gallons per day of twenty-four hours. There is a level strip of beach immediately south of the present plant, and this offers the best site for the construction of the additions. The wier now in the mixing box of the present plant must be calibrated so that the quantity of sewage fed to the present septic tank will never exceed two hundred and fifty thousand gallons per day. All of the excess will flow by means of a twelve inch cast iron pipe to the mixing chamber of the new plant. The overflow wier at the mixing box of the old plant may be automatically raised and lowered by means of a float, and this automatic device can readily be regulated to properly divide the sewage between the two plants. It will also be possible to lessen the quantity of sewage flowing to the old plant at times when the beds are clogged, or the septic tank or distributing device are out of order.

The sewage coming to the new plant will be fed into a mixing box six feet by twenty-four feet, by eight feet deep. This is shown on Plate 2, which is a plan of the proposed addition to the present plant. The north wall of the mixing box is to be fitted up with eight eight inch shear valves, four leading into each sedimentation chamber. These valves will be set seven feet from the bottom of the sedimentation chambers,

so that they will be two feet below the normal surface of the sewage in these latter. This will prevent undue agitation of the sediment or the surface scum by the entering sewage.

The sedimentation tanks are to be two in number, and each twelve feet wide, thirty feet long and an average of eight feet deep. The bottoms of the sedimentation chambers shall be eight feet six inches deep at the north end, where the sewage enters, and shall slope to a depth of seven feet six inches at the south end . The volume of each tank will then be 2880 cu. ft., or 21,500 gallons. When the plant is treating 455,000 gallons of sewage per day, the liquid will travel through the sedimentation chambers at a rate of thirteen and one-third feet per hour, or 2.66 inches per minute. This will be sufficient to allow the sand, silt or other heavy particles to settle to the bottom.

From the sedimentation chambers the sewage will pass through eight eight inch shear valves at the south ends of the tanks, into a channel (marked "A" on Plate II) which will allow of its entry into either of the three hydrolytic tanks.

The hydrolytic tanks will be three in number, (marked "B", "C" & "D" on Plate II), and each tank will be eighty feet long and seven feet six inches deep at its north end, where the sewage enters, and six feet six inches deep at its south end. The tank "B" will be six feet wide, "C" will be eight feet wide, while the tank "D" will be ten feet wide. Each tank will be fed through two ten inch shear valves, leading from the distributing channel, and set in the north wall of the tank, at an elevation of three feet from the normal surface of the sewage in the tanks. When the plant is treating 455,000 gallons

of sewage per day, the rate of travel through the hydrolytic tanks, assuming that each tank receives its part of the whole volume in proportion to its size, will be about fifteen feet per hour, or at the rate of three inches per minute. The sewage will remain in the hydrolytic tanks for about five hours, making the total rest period in the sedimentation and hydrolytic tanks combined, seven and one-half hours.

At times of extreme dry weather flow the total volume of sewage will be far less than 455,000 gallons per day, and in order that the sewage does not remain in the septic tank so long as to render it too foul for satisfactory treatment in the filters, one of the hydrolytic tanks may be cut out entirely. By using but one of the three hydrolytic tanks alone, or by using a combination of any two of them, it will be possible to keep the same velocity of flow when the plant is treating only 25%, 33%, 42%, 58% or 75% of the rated capacity of the plant.

From the hydrolytic tank the sewage will flow over a weir, which will be protected by a scum board, into the dosing chamber. This will be twenty-four feet wide, thirty feet long and four feet deep. The west and south sides of the dosing tanks will be depressed six inches, in order to accommodate ten automatic delivering siphons, constructed after the manner specified in the Miller Patents. The total volume of the dosing tank will be three thousand cubic feet, or about twenty-two thousand five hundred gallons. Each time the tank fills one of the siphons will deliver the entire contents through a twelve inch pipe to one of the sand filters. There will be one siphon

for each filter bed, and a separate pipe must be provided from each siphon to its respective bed. The feeding device will automatically prime the ten siphons in rotation, so that the beds will be dosed one after the other.

The walls of the septic tanks and sedimentation tanks, as well as those of the dosing chamber, are to be of reinforced concrete, and the bottoms of all tanks are to be composed of six inches of unreinforced concrete, laid on six inches of well compacted cinders, after the foundation has been thoroughly tamped and rolled. The depth of all tanks given above is understood to be measured from the normal surface of the water in the tanks, which will be on a level with the brink of the weir at the entrance to the dosing chamber.

When the plant is treating 455,000 gallons of sewage per day the dosing tank will be filled twenty times in twenty-four hours. Each filter bed will then receive two doses of twenty-two thousand five hundred gallons each in one day. This gives a normal rate of filtration of about two hundred and ninety thousand gallons per acre per day. The present plant treats three hundred thousand gallons per acre per day, and since satisfactory results are obtained at this rate, it should prove equally satisfactory for the new plant.

In case there is any trouble with the beds, either from clogging or from freezing, there will be a twelve inch pipe laid from the dosing chamber to the manhole between beds 1 and 2, so that the septic effluent may be run directly to the lake outfall without filtration.

The sand filter beds will be ten in number, and of the

dimensions shown on Plate II. Each bed will have an area of sixty-five hundred square feet, and a depth of six feet. The sewage will be led to the bed by a twelve inch pipe, at the mouth of which a concrete opening will be built, to prevent washing out of the sand at the entrance to the bed. The sewage will flow from the feed pipe onto a wooden trough twelve inches wide and three inches deep, which will be laid on the surface of the bed, in the position shown on the plan of the beds, (Plate II). The main trough will have branches so arranged as to reach all parts of the bed, and the sides of these branches will contain one inch square holes at the level of the bottom of the trough, so that the sewage will flow out over the surface of the sand without seriously disturbing the latter.

The filter beds are to be constructed by excavating the sand on the shore of the lake, over the area to be occupied by the bed, to a depth of seven feet below the elevation of the outlet from the feed pipe. The bottom is then to be leveled off and rolled. The sand which is removed in the excavation is to be screened to remove all gravel that will not pass a one-quarter inch screen. The bottom of the bed is to be laid with six inch tile drains, in the position shown on Plate II, and sloped true to grade to the main twelve inch pipe drain leading from the bed. The drain tile is then to be covered with one foot of coarse gravel, all of which will be retained on a one-half inch ring, and none of which will be retained on a one inch ring. This layer of gravel is to be carefully leveled and compacted, and the sand is then to be deposited upon it to the requisite depth. The cast iron drain pipes are to pass

beneath the bed and connect to the pipe in the next bed. These cast iron drains are to be laid six inches lower than the tile feeding drains in each bed, and there is to be a brick manhole between each two beds, which shall have a diameter of three feet.

The drain pipe from the filter beds leads to the present outfall pipe at the lake shore. Three protection piers will have to be constructed in the positions shown on Plate II, each extending out into the lake one hundred feet. These piers shall be ten feet wide and shall consist of three layers of Wakefield sheet piling, properly tied with iron rods at intervals of eight feet, and suitably bulkheaded to prevent bulging. The sheet piling shall be twenty feet long and shall be driven to within three feet of the mean water level. The piers are to be filled with rock of a one-man size, or with cement mortar of a 1:3 mixture deposited in paper bags holding at least one-half cu. ft. each.

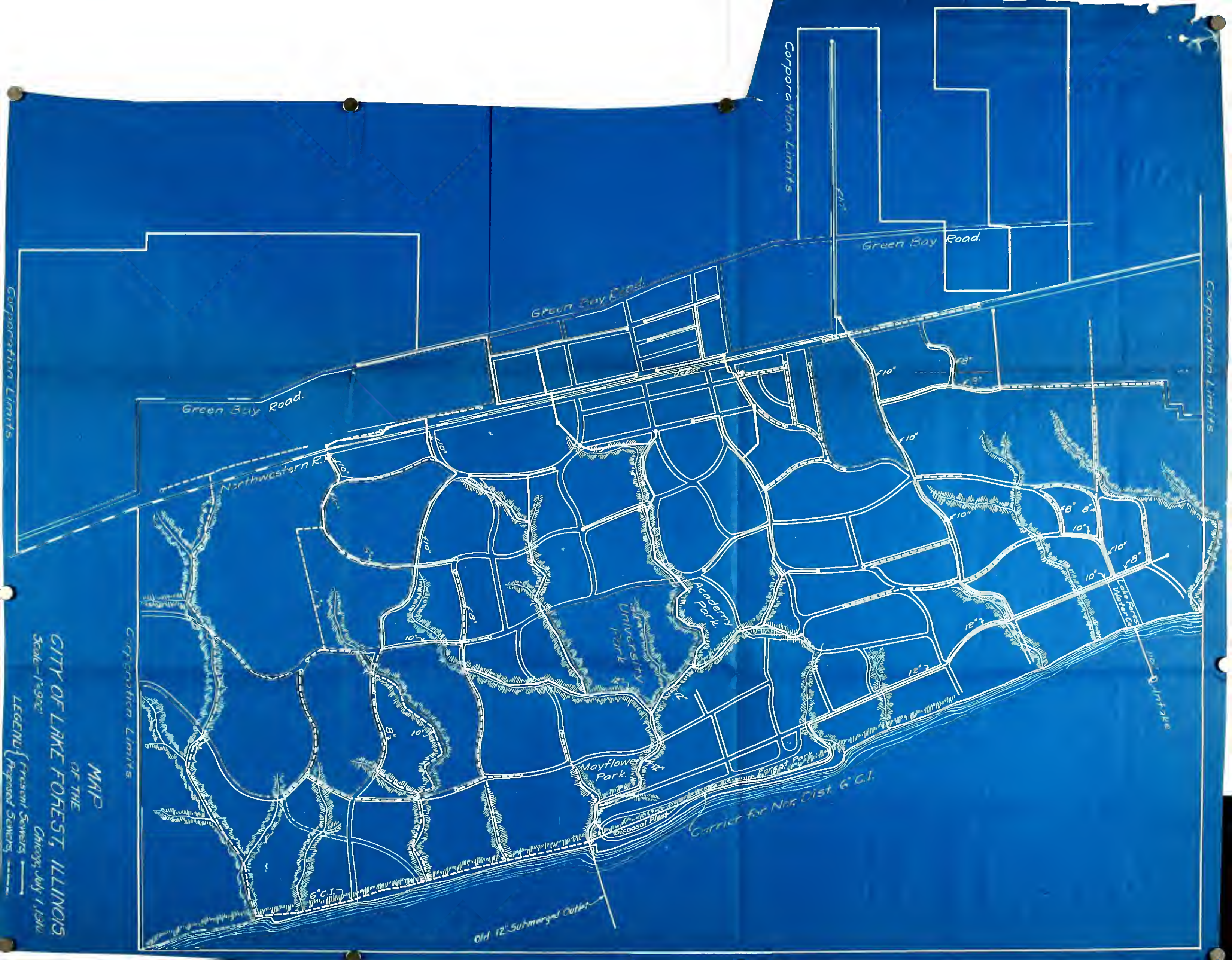
The sludge from the hydrolytic tanks will be drawn into the sedimentation tanks whenever it is found necessary, and the sludge from the latter tanks will be withdrawn through the ten inch sludge pipe "G" to a sludge bed. This will merely be a depressed area 35 ft. by 25 ft., with a bank of sand about it to retain the moisture in the sludge and allow it to gradually seep into the ground.

The sewage tanks will be enclosed in a building formed by continuing the outer sides of the tanks to a height of ten feet above ground level, and covering with a wooden roof. There shall be a door at each end of the building, and one window at the east side of the dosing tank. This window shall be kept covered

to shut out the light during ordinary working.

An installation built after the above general design will properly purify the sewage of the city, and will be ample to treat the storm water and take care of whatever increase in quantity is likely to be produced in the future at this locality. The cost of the addition appliances is estimated as follows:

410 cu. yds. of concrete at $10.00 (including reinforcement)	$4100.00
Ten thousand B.M. lumber, at $30.00 per M.	300.00
750 lin. ft. of 12" C. I. pipe, at $1.10	825.00
2500 lin. ft. vitrified clay pipe (12") at $.40	1000.00
3500 lin. ft. unglazed tile (6"), at $10.00 per hundred feet	350.00
7000 brick for manholes, at $15.00 per thousand (in plade)	105.00
10 manhole covers, at $1.00 each	10.00
22 shear valves, at $2.50 each	55.00
Automatic siphons, piping, rigging, etc.	500.00
Excavation, grading, etc., (18,000 cu. yds.)	3600.00
Screening and washing sand and surfacing beds	1100.00
Three protection piers	1200.00
Incidentals, superintendence, and engineering, 10%	1315.00
Total	$14,460.00



MAP
OF THE
CITY OF LAKE FOREST, ILLINOIS.

Scale–1"=900'

Chicago, July 1, 1912.

LEGEND { Present Sewers ━━
Proposed Sewers - - -

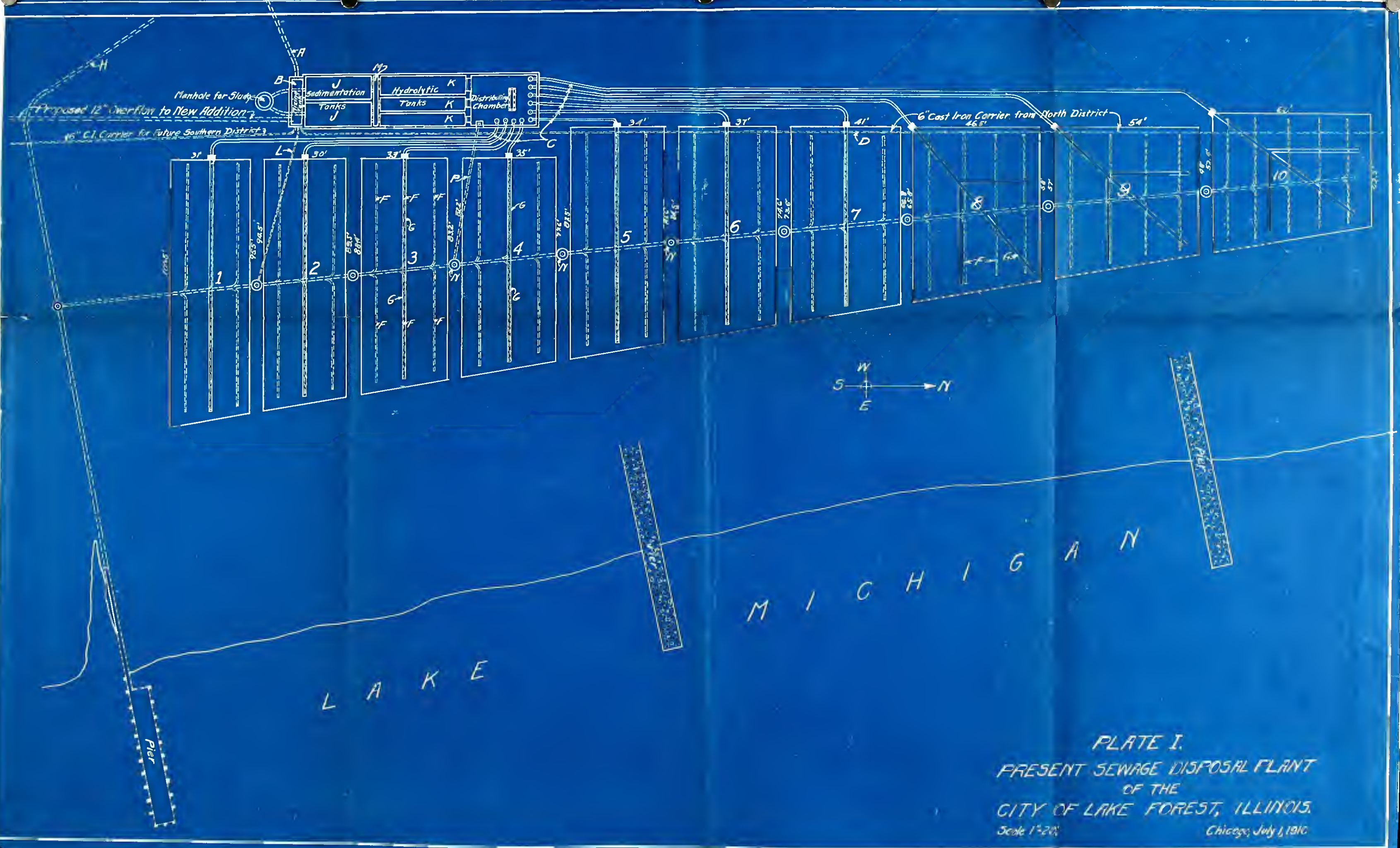


PLATE I.

PRESENT SEWAGE DISPOSAL PLANT
OF THE
CITY OF LAKE FOREST, ILLINOIS.

Scale 1"=20'.

Chicago, July 1, 1910.

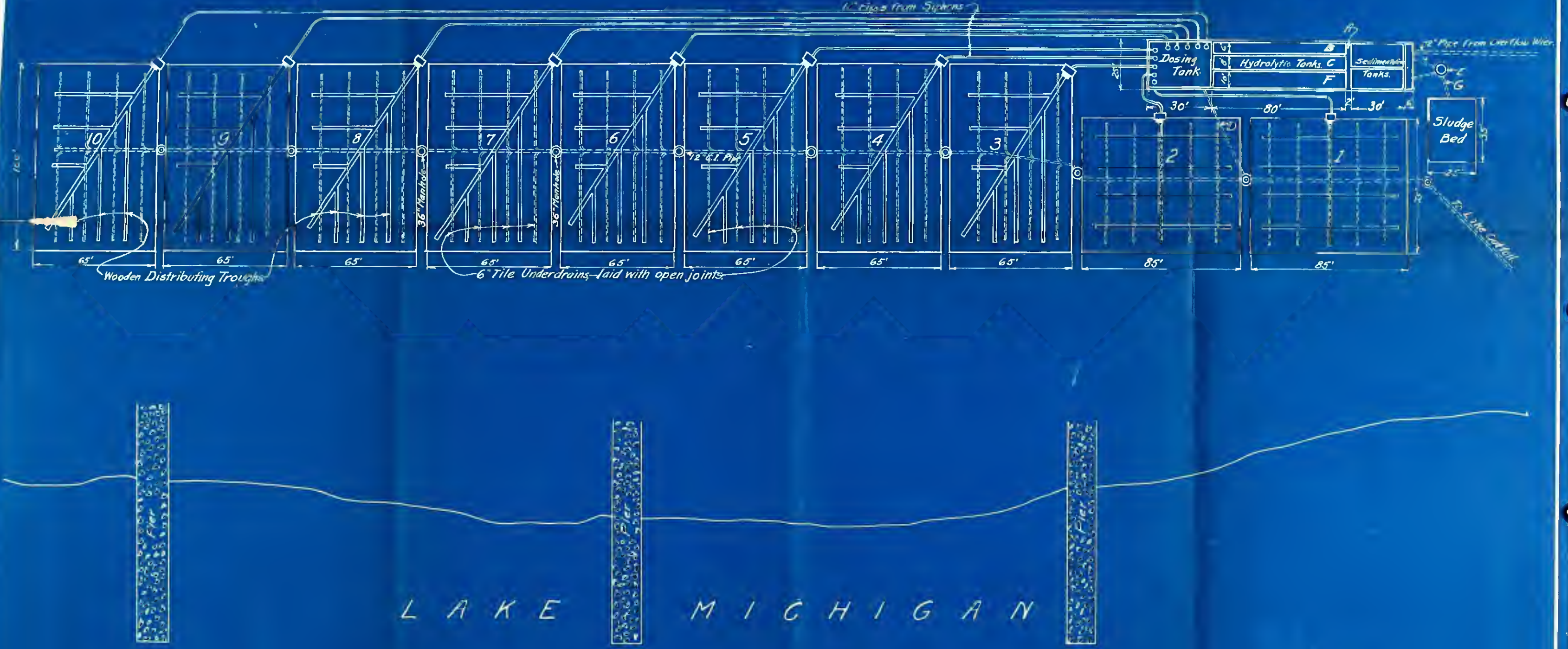


PLATE II.

PROPOSED ADDITIONAL SEWAGE DISPOSAL PLANT FOR THE CITY OF LAKE FOREST, ILLINOIS.

Scale—1"=32'.

Chicago, July 1, 1910.